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Washington, D.C. 20231

Re: Applicant(s) or Identifier: Sadayuki Abeta et al.
Serial No. : To be Assigned
Filed : Concurrently Herewith
Title : CHANNEL ESTIMATION UNIT, AND CDMA RECEIVER AND
CDMA TRANSCEIVER WITH CHANNEL ESTIMATION UNIT

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Kindly file the annexed papers indicated below:

- ☒ Verified Translation of Application for Patent including Specification (40 pages) and Formal Drawing(s) (12 sheets)
☒ Declaration and Power of Attorney (3 pages)
☐ Declaration(s) Claiming Small Entity Status
☐ Information Disclosure Statement and copies of reference(s)
☒ Assignment for recordation and Assignment Cover Sheet
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☒ PCT/IB/308
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The fee has been calculated as follows:

	Claims	Claims Paid for	Extra	Rate (Sm. Ent.)	Fee	Rate	Fee
BASIC FILING FEE				\$ 380	\$	\$ 760	\$760
Total	14	- 20 =	0	x \$9	\$	x \$18	\$
Indep.	6	- 3 =	3	x \$39	\$	x \$78	\$234
MULTIPLE DEPENDENT CLAIM PRESENT				+ \$130	\$	+ \$260	\$
TOTAL					\$		\$994

☒ A check in the amount of \$994.00 is enclosed.
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The Commissioner is hereby authorized to charge any deficiency in the fee or credit any overpayment to the undersigned attorney's Deposit Account No. 02-4270.

Respectfully submitted,

Dated: August 17, 1999

By:

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant(s) : Sadayuki Abeta et al.

Serial No. : To be assigned Examiner : To be assigned

Filing Date : Concurrently herewith Group Art Unit :

Title : CHANNEL ESTIMATION UNIT, AND CDMA RECEIVER
AND CDMA TANSCEIVER WITH CHANNEL ESTIMATION
UNIT

Assistant Commissioner for Patents
Washington, D.C. 20231

PRELIMINARY AMENDMENT

Sir:

Concurrently with the filing of the above-referenced application and prior to the substantive examination thereof, please amend the above-referenced application as follows:

IN THE CLAIMS

Please amend claims 6-11 as follows:

--6. (Amended) The CDMA transceiver as claimed in [any one of claims 3-5] claim 3, wherein said receiving processor further comprises means for extracting, from the data symbol sequence compensated for, the power control symbol sequence for controlling power of the data symbols and pilot symbols, and said means for transmitting the spread combined symbol sequence transmits the spread combined symbol sequence in accordance with the power control symbol sequence.--

--7. (Amended) The equipment as claimed in [any one of claims 1-6] claim 1, wherein the power of the data symbols and pilot symbols is controlled on a slot by slot basis.--

--8. (Amended) The equipment as claimed in [any one of claims 1-7] claim 1, wherein the number of data symbols included in each slot of the combined symbol sequence is the same, and the number of pilot symbols included in each slot of the combined symbol sequence is the same.--

--9. (Amended) The equipment as claimed in [any one of claims 1-8] claim 1, wherein the pilot blocks each consist of all the pilot symbols in each slot.--

--10. (Amended) The equipment as claimed in [any one of claims 1-9] claim 1, wherein when obtaining the channel estimates of the data symbols in an nth slot in the combined symbol sequence, where n is an integer, the pilot blocks are generated from (n-K+1)th slot to (n+K)th slot in the combined symbol sequence, where K is a natural number.--

--11. (Amended) The equipment as claimed in [any one of claims 1-10] claim 1, wherein the pilot blocks closer to the data symbol with which the channel estimate is to be obtained have a greater weight.--

REMARKS

Claims 1-14 are pending in this application.


After entry of this amendment to eliminate multiple dependencies in claims 6-11, it is believed that the above-referenced application is ready for substantive consideration by the Examiner. Early and favorable examination thereof is, therefore, respectfully requested.

In the event that additional cooperation in this case may be helpful to complete its prosecution, the Examiner is cordially invited to contact Applicants' representative at the telephone number listed below.

The Commissioner is hereby authorized to charge any insufficient fees or credit any overpayment associated with the above-identified application to Deposit Account No. 02-4270.

Respectfully submitted,

Dated: August 17, 1999


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02-4270-3815

DESCRIPTION

TITLE OF THE INVENTION

5 CHANNEL ESTIMATION UNIT, AND CDMA RECEIVER AND
CDMA TRANSCEIVER WITH CHANNEL ESTIMATION UNIT

TECHNICAL FIELD

664430 900946
The present invention relates to an apparatus
10 that has a plurality of slots and makes channel
estimation (propagation path estimation) of data
symbols from pilot symbols in a combined symbol
sequence including the data symbols and pilot
symbols, and a CDMA (Code Division Multiple Access)
15 receiver and CDMA transmitter with the apparatus.

BACKGROUND ART

In a mobile communications environment,
amplitude and phase fluctuations in a traffic
20 channel can occur because of Rayleigh fading due to
changes in the relative location between a mobile
station and a base station. Thus, in a conventional
phase modulation scheme that transmits data
(information) by the phase of a carrier, it is
25 common for a transmitting side to carry out
differential encoding of transmitted data for

impressing the data on relative phases of neighboring symbols, and for a receiving side to discriminate and decide the data by differential detection.

5 However, since the transmitted data is subjected to the differential encoding as mentioned above, a one-bit error in a radio section appears as a two-bit error in the differential detection, thereby increasing the receiving error rate by 3 dB in terms
10 of the SNIR (Signal-to-Noise Interference power Ratio) as compared with coherent detection like binary phase-shift keyed modulation (BPSK modulation).

On the other hand, although absolute coherent
15 detection, which discriminates and decides the phase of a received signal using the absolute phase of each data symbol, has a highly efficient receiving characteristic, it is difficult under the Rayleigh fading environment to decide the absolute phase of
20 the reception.

In regard to this matter, reference 1, Seiichi Sampei and Terumi Sunaga, "Rayleigh Fading Compensation for QAM in Land Mobile Radio Communication", IEEE Trans. Vehicular Technol., VT-
25 42, No. 2, May 1993 proposes a method of estimating and compensating for fading distortion using pilot

5 symbols that are inserted in data symbols at fixed intervals, and have known phases. In the reference 1, a pilot symbol is inserted at every several data symbols so as to carry out the channel estimation based on the received phase of the pilot symbol. More specifically, using the pilot symbols before and after the data symbol section, the method measures the amplitude and phase of a received signal of each path of each user, and estimates and compensates for channel fluctuations in the data symbol section by interpolating the values measured.

On the other hand, reference 2, Hidehiro Ando et al., "Channel Estimation Filter Using Time-Multiplexed Pilot Channel for Coherent RAKE Combining in DS-CDMA Mobile Radio", IEICE Trans. Commun. Vol. 81-B, No. 7, July 1998 proposes a method of carrying out channel estimation with higher accuracy by performing the channel estimation using more pilot symbols.

20 Fig. 11 illustrates a channel estimation method disclosed in the reference 2. This method carries out transmission power control on a slot by slot basis to follow instantaneous Rayleigh fluctuations. Accordingly, as shown in Fig. 11, the amplitude (power) of a combined symbol sequence consisting of the data symbols and pilot symbols varies slot by

slot, and its phase also varies slightly due to the operation of an amplifier in transmission. Such transmission power control enables a reverse channel of the DS-CDMA (Direct Sequence CDMA) to maintain
5 the SNIR against interference signals due to cross-correlation from other users.

The channel estimation of data symbols is performed using the pilot symbols inserted into the data symbols at fixed intervals. More specifically,
10 it obtains its channel estimates $\hat{\xi}$ by averaging (coherently adding) pilot symbols $\hat{\xi}$ (estimated complex fading envelope) in multiple slots before and after the slot to which the data symbols to be estimated belong, and then by summing the averages
15 weighted by weighting factors a . Highly accurate channel estimation is carried out in this manner.

With such channel estimation using many pilot symbols belonging to different slots, this method can achieve the channel estimation at higher
20 accuracy. This is because although the power of the pilot symbols fluctuates in the multiple slots, and channel estimation error takes place due to the power fluctuations, an effect of reduction in thermal noise and interference signals obtained by
25 using pilot symbols in many slots is greater than the channel estimation error.

However, it is difficult for the method of the reference 2 to achieve the channel estimation with further accuracy because it considers the channel fluctuations in the individual slots are small, and obtains the channel estimates $\tilde{\xi}$ using the same weighting factor a for all the data symbols in each slot.

For example, as shown in Fig. 11, this method uses, even for the $(m-A)$ th data symbol or the $(m+B)$ th data symbol in the n th slot, where A and B are natural numbers, the same weighting factors $a(0)$, $a(1)$ and the like to obtain their channel estimates $\tilde{\xi}(n)$.

However, with regard to the $(m-A)$ th data symbol, it will be reasonable to assign a greatest weight to the pilot symbols in the n th slot because they are closest (in time) to the $(m-A)$ th data symbol, and hence best reflect the channel state at the time the data symbol is transmitted.

In contrast with this, with regard to the $(m+B)$ th data symbol, it will be reasonable to assign a greatest weight to the pilot symbols in the $(n+1)$ th slot because they are closest (in time) to the $(m+B)$ th data symbol, and hence best reflect the channel state at the time the data symbol is transmitted.

Thus, the channel estimates should be obtained by assigning proper weighting factors to individual data symbols even though they belong to the same slot.

5 Fig. 12 illustrates an example of received envelope fluctuations due to fading. Points 1205, 1210, 1215, 1220 and 1225 indicate in fast fading the values of a received envelope at fixed time intervals. Points 1255, 1260, 1265 and 1270
10 indicate in slow fading the values of a received envelope at the same fixed time intervals.

 The received envelope fluctuations are greater in the fast fading than in the slow fading. Accordingly, it is important especially in the fast
15 fading to carry out the highly accurate channel estimation by assigning proper weighting factors to individual data symbols even though they belong to the same slot.

20 DISCLOSURE OF THE INVENTION

 The present invention is implemented to solve the foregoing problems. It is therefore an object of the present invention to achieve highly accurate channel estimation by obtaining highly accurate
25 channel estimates by assigning appropriate weighting factors to individual data symbols in the same slot,

and by calculating a sum of appropriately weighted pilot symbols in respective slots before and after the slot the data symbols belong to, when carrying out the channel estimation of the data symbols.

5 The highly accurate channel estimation and compensation for channel fluctuations in the data symbols based on the channel estimation make it possible for the absolute coherent detection to decide the absolute phase of each data symbol even
10 in the Rayleigh fading environment, which can reduce the SNIR for achieving desired receiving quality (receiving error rate). This can reduce the transmission power, and increase the capacity of a system in terms of the number of simultaneous
15 subscribers.

 In order to accomplish the object
aforementioned, according to the invention as claimed in claim 1, a channel estimation unit for obtaining channel estimates of data symbols from
20 pilot symbols in a combined symbol sequence which has a plurality of slots and includes the data symbols and the pilot symbols, comprises:

 means for locating the pilot symbols in the combined symbol sequence;

25 means for generating pilot blocks by extracting the pilot symbols from two or more slots in the

combined symbol sequence in accordance with a
located result; and

means for obtaining the channel estimates of the
data symbols by calculating a weighted sum of
5 averages of the pilot symbols in the individual
pilot blocks,

wherein a magnitude of weighting differs between
at least two data symbols in each slot.

According to the invention as claimed in claim
10 2, a CDMA receiver which receives a combined symbol
sequence that is spread, has a plurality of slots,
and includes data symbols and pilot symbols, and
which generates a data sequence, comprises:

means for receiving the spread combined symbol
15 sequence;

means for generating a combined symbol sequence
by despreading the spread combined symbol sequence;

means for locating the pilot symbols in the
combined symbol sequence;

20 means for generating pilot blocks by extracting
the pilot symbols from two or more slots in the
combined symbol sequence in accordance with a
located result;

means for obtaining channel estimates of the
25 data symbols by calculating a weighted sum of
averages of the pilot symbols in the individual

pilot blocks;

means for obtaining a data symbol sequence by eliminating the pilot symbols from the combined symbol sequence in accordance with the located

5 result;

means for compensating for channel fluctuations in the data symbol sequence by using the channel estimates of the data symbols; and

means for generating the data sequence by demodulating the data symbol sequence compensated for,

wherein a magnitude of weighting differs between at least two data symbols in each slot.

According to the invention as claimed in claim 15 3, a CDMA transceiver including a transmitting processor and a receiving processor, comprises:

means for generating a data symbol sequence by modulating a data sequence;

means for generating a combined symbol sequence 20 by inserting pilot symbols into the data symbol sequence;

means for generating a spread combined symbol sequence by spreading the combined symbol sequence; and

25 means for transmitting the spread combined symbol sequence,

wherein the spread combined symbol sequence to be transmitted has a plurality of slots, and the receiving processor comprises:

means for receiving the spread combined symbol
5 sequence;

means for generating the combined symbol sequence by despreading the spread combined symbol sequence;

means for locating the pilot symbols in the
10 combined symbol sequence;

means for generating pilot blocks by extracting the pilot symbols from two or more slots in the combined symbol sequence in accordance with a located result;

15 means for obtaining channel estimates of the data symbols by calculating a weighted sum of averages of the pilot symbols in the individual pilot blocks;

means for obtaining a data symbol sequence by
20 eliminating the pilot symbols from the combined symbol sequence in accordance with the located result;

means for compensating for channel fluctuations in the data symbol sequence by using the channel
25 estimates of the data symbols; and

means for generating the data sequence by

demodulating the data symbol sequence compensated
for,

wherein a magnitude of weighting differs between
at least two data symbols in each slot.

5 According to the invention as claimed in claim
4, in the CDMA transceiver as claimed in claim 3,
the transmitting processor further comprises means
for inserting into the data symbol sequence a power
control symbol sequence for controlling power of the
10 data symbols and pilot symbols.

 According to the invention as claimed in claim
5, in the CDMA transceiver as claimed in claim 4,
the receiving processor further comprises means for
measuring from the pilot symbols a signal-to-noise
15 and interference power ratio, and for generating the
power control symbol sequence from the signal-to-
noise and interference power ratio.

 According to the invention as claimed in claim
6, in the CDMA transceiver as claimed in any one of
20 claims 3-5, the receiving processor further
comprises means for extracting, from the data symbol
sequence compensated for, the power control symbol
sequence for controlling power of the data symbols
and pilot symbols, and the means for transmitting
25 the spread combined symbol sequence transmits the
spread combined symbol sequence in accordance with

the power control symbol sequence.

According to the invention as claimed in claim 7, in the equipment as claimed in any one of claims 1-6, the power of the data symbols and pilot symbols
5 is controlled on a slot by slot basis.

According to the invention as claimed in claim 8, in the equipment as claimed in any one of claims 1-7, the number of data symbols included in each slot of the combined symbol sequence is the same,
10 and the number of pilot symbols included in each slot of the combined symbol sequence is the same.

According to the invention as claimed in claim 9, in the equipment as claimed in any one of claims 1-8, the pilot blocks each consist of all the pilot
15 symbols in each slot.

According to the invention as claimed in claim 10, in the equipment as claimed in any one of claims 1-9, when obtaining the channel estimates of the data symbols in an n th slot in the combined symbol
20 sequence, where n is an integer, the pilot blocks are generated from $(n-K+1)$ th slot to $(n+K)$ th slot in the combined symbol sequence, where K is a natural number.

According to the invention as claimed in claim 25 11, in the equipment as claimed in any one of claims 1-10, the pilot blocks closer to the data symbol

with which the channel estimate is to be obtained have a greater weight.

According to the invention as claimed in claim 12, a channel estimation method of obtaining channel estimates of data symbols from pilot symbols in a combined symbol sequence which has a plurality of slots and includes the data symbols and the pilot symbols, comprises the steps of:

10 locating the pilot symbols in the combined symbol sequence;

generating pilot blocks by extracting the pilot symbols from two or more slots in the combined symbol sequence in accordance with a located result; and

15 obtaining the channel estimates of the data symbols by calculating a weighted sum of averages of the pilot symbols in the individual pilot blocks,

wherein a magnitude of weighting differs between at least two data symbols in each slot.

20 According to the invention as claimed in claim 13, a CDMA receiving method of generating a data sequence by receiving a combined symbol sequence that has a plurality of slots, includes data symbols and pilot symbols, and is spread, comprises the steps of:

25 receiving the spread combined symbol sequence;

generating the combined symbol sequence by
despreading the spread combined symbol sequence;

locating the pilot symbols in the combined
symbol sequence;

5 generating pilot blocks by extracting the pilot
symbols from two or more slots in the combined
symbol sequence in accordance with a located result;

obtaining channel estimates of the data symbols
by calculating a weighted sum of averages of the
10 pilot symbols in the individual pilot blocks;

obtaining a data symbol sequence by eliminating
the pilot symbols from the combined symbol sequence
in accordance with the located result;

compensating for channel fluctuations in the
15 data symbol sequence by using the channel estimates
of the data symbols; and

generating the data sequence by demodulating the
data symbol sequence compensated for,

wherein a magnitude of weighting differs between
20 at least two data symbols in each slot.

According to the invention as claimed in claim
14, a CDMA transmitting and receiving method
comprises the steps of:

on a transmitting side,

25 generating a data symbol sequence by modulating
a data sequence;

generating a combined symbol sequence by
inserting pilot symbols into the data symbol
sequence;

generating a spread combined symbol sequence by
5 spreading the combined symbol sequence; and

transmitting the spread combined symbol
sequence,

wherein the spread combined symbol sequence to
be transmitted has a plurality of slots, and
10 on a receiving side,

receiving the spread combined symbol sequence;

generating the combined symbol sequence by
despreading the spread combined symbol sequence;

locating the pilot symbols in the combined
15 symbol sequence;

generating pilot blocks by extracting the pilot
symbols from two or more slots in the combined
symbol sequence in accordance with a located result;

obtaining channel estimates of the data symbols
20 by calculating a weighted sum of averages of the
pilot symbols in the individual pilot blocks;

obtaining a data symbol sequence by eliminating
the pilot symbols from the combined symbol sequence
in accordance with the located result;

25 compensating for channel fluctuations in the
data symbol sequence by using the channel estimates

of the data symbols; and

generating the data sequence by demodulating the
data symbol sequence compensated for,

wherein a magnitude of weighting differs between
5 at least two data symbols in each slot.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a block diagram showing a
configuration of a channel estimation unit as a
10 first embodiment in accordance with the present
invention;

Fig. 2 is a flowchart illustrating a channel
estimation processing by the channel estimation unit
of the first embodiment in accordance with the
15 present invention;

Fig. 3 is a diagram illustrating, taking an
example of the channel estimation, the principle of
operation of the channel estimation by the channel
estimation unit of the first embodiment in
20 accordance with the present invention;

Fig. 4 is a block diagram showing a
configuration of a CDMA receiver as a second
embodiment in accordance with the present invention;

Fig. 5 is a flowchart illustrating a receiving
25 processing by the CDMA receiver of the second
embodiment in accordance with the present invention;

Fig. 6 is a block diagram showing a configuration of a CDMA transceiver as a third embodiment in accordance with the present invention;

Fig. 7 is a block diagram showing a
5 configuration of a transmitting processor of the CDMA transceiver of the third embodiment in accordance with the present invention;

Fig. 8 is a block diagram showing a configuration of a receiving processor of the CDMA
10 transceiver of the third embodiment in accordance with the present invention;

Fig. 9 is a flowchart illustrating a transmitting processing by the transmitting processor of the CDMA transceiver of the third
15 embodiment in accordance with the present invention;

Fig. 10 is a diagram illustrating an example which inserts power control symbols into a combined symbol sequence;

Fig. 11 is a diagram illustrating the principle
20 of the channel estimation operation by a related art; and

Fig. 12 is an example illustrating received envelope fluctuations due to fading.

25 BEST MODE FOR CARRYING OUT THE INVENTION

Best modes for implementing the present

invention will now be described in detail with reference to the accompanying drawings.

[FIRST EMBODIMENT]

Fig. 1 is a block diagram showing a
5 configuration of a channel estimation unit as a first embodiment in accordance with the present invention. A channel estimation unit 100 of the present embodiment obtains channel estimates of data symbols from pilot symbols in a combined symbol
10 sequence that has a plurality of slots and includes the data symbols and pilot symbols.

The channel estimation unit 100 comprises a slot alignment detector 101, a pilot block generator 111 and a channel estimate acquisition section 121.
15 Although the channel estimation unit 100 is implemented in the form of software using a DSP (Digital Signal Processor) (together with a memory that stores programs) in the present embodiment, it can be implemented in the form of hardware, in which
20 case, components such as delay circuits are used as needed.

Fig. 2 is a flowchart illustrating a channel estimation processing by the channel estimation unit of the present embodiment, and Fig. 3 is a diagram
25 illustrating, taking an example that obtains the channel estimate of an m th data symbol in an n th

slot (m and n are integers), the operation principle of the channel estimation unit of the present embodiment.

In the example of Fig. 3, the combined symbol
5 sequence undergoes the transmission power control on a slot by slot basis. Although each slot of the combined symbol sequence in Fig. 3 consists of pilot symbols of a fixed length, followed by data symbols of a fixed length, each slot may consist of a single
10 pilot symbol and a single data symbol, or a variable length pilot and data symbols. Alternatively, slots are allowable that consist of only data symbols or pilot symbols. Furthermore, the arrangement of the data symbols and pilot symbols can be determined
15 freely.

First, at step S201 in Fig. 2, the slot alignment detector 101 locates the pilot symbols in the combined symbol sequence.

At step S202, the pilot block generator 111
20 extracts the pilot symbols from two or more slots of the combined symbol sequence in accordance with the locating result, and generates a plurality of pilot blocks. In the example of Fig. 3, it extracts pilot symbols from $(n-K+1)$ th to $(n+K)$ th slot of the
25 combined symbol sequence, where K is a natural number which is three in Fig. 3, thereby generating

the pilot blocks. A pilot block is defined as a set of pilot symbols.

Although the pilot blocks each consist of all the pilot symbols in a slot, they can be formed using part of the pilot symbols in the slot. Besides, a pilot block can consist of a single pilot symbol. In addition, the number of the pilot symbols in the individual pilot blocks can be varied from slot to slot.

10 To obtain the channel estimate of the data symbols in the n th slot, it is not necessary to generate nearly the same number of pilot blocks before and after the n th slot as in the example of Fig. 3. Thus, considering the delay of the channel estimation, the pilot blocks can be generated only from the slots with the number smaller than (previous to) the n th slot.

At steps S203-S206, the channel estimate acquisition section 121 obtains the channel estimates of the data symbols. First, at step S203, the channel estimate acquisition section 121 calculates an average of the pilot symbols $\hat{\xi}$ (estimated complex fading envelope) in each pilot block to obtain the pilot block average $\bar{\xi}$, which is carried out for all the pilot blocks (step S204). When each pilot block consists of only one pilot

symbol, the pilot symbol $\hat{\xi}$ itself becomes the pilot block average $\bar{\xi}$. In the example of Fig. 3, the pilot block averages $\bar{\xi}(n+i)$ are each obtained for the pilot blocks in the $(n+i)$ th slot ($i = -K+1$ to K , where $K=3$).

At step S205, the channel estimates $\tilde{\xi}$ of the data symbol is obtained by calculating the weighted sum of the pilot block averages $\bar{\xi}$ which are weighted by the weighted factors a . In the example of Fig. 3, the channel estimate $\tilde{\xi}(m,n)$ of the m th data symbol in the n th slot is obtained by placing the weights of the $(n+i)$ th pilot block at $a(m,i)$. The channel estimate $\tilde{\xi}(m,n)$ is given by the following equation (1).

$$\tilde{\xi}(m, n) = \sum_{i=-K+1}^K \alpha(m,i) \cdot \bar{\xi}(n+i) \quad (1)$$

It is preferable to increase the weights $a(m,i)$ of the pilot blocks that are closer (in time) to the data symbol (m th data symbol in the n th slot) whose channel estimate is to be obtained. This is because such pilot blocks can be considered to represent the state of the propagation path during the transmission of that data symbol more correctly

because the propagation path fluctuates at every moment.

For example, with regard to the $(m-A)$ th data symbol (A is a natural number) in the n th slot in Fig. 3, it is preferable to maximize the weight of the pilot block in the n th slot. In contrast, with regard to the $(m+B)$ th data symbol (B is a natural number) in the n th slot, it is preferable to maximize the weight of the pilot block in the $(n+1)$ th slot.

The channel estimate acquisition section 120 iterates the foregoing step S205 for all the data symbols with which the channel estimates must be obtained (step S206).

Thus, highly accurate channel estimates can be obtained.

[SECOND EMBODIMENT]

Fig. 4 is a block diagram showing a configuration of a CDMA receiver as a second embodiment in accordance with the present invention. A CDMA receiver 400 of the present embodiment receives a spread combined symbol sequence which has a plurality of slots including data symbols and pilot symbols, and generates the data sequence.

The CDMA receiver 400 comprises a receiving

section 410, a matched filter 425, a slot alignment
detector 401, a pilot block generator 411, a channel
estimate acquisition section 421, a pilot symbol
eliminator 429, a data symbol sequence compensator
5 430, a RAKE combiner 432, a deinterleaver 434 and a
Viterbi decoder 436. Although these components such
as the matched filter 425, slot alignment detector
401 and so forth are implemented in the form of
software using a DSP (and a memory that stores
10 programs) 420 as shown in Fig. 4 in the present
embodiment, they can be implemented with hardware.
The structure and functions of the slot alignment
detector 401, pilot block generator 411 and channel
estimate acquisition section 421 are the same as
15 those of their counterparts in the channel
estimation unit 100 of the first embodiment in
accordance with the present invention.

Fig. 5 is a flowchart illustrating a receiving
processing by the CDMA receiver of the present
20 embodiment in accordance with the present invention.
First, at step S501, the receiving section 410
receives the received signal, that is, the spread
combined symbol sequence.

At step S502, the matched filter 425 despreads
25 the received signal to generate the combined symbol
sequence.

At step S503, the slot alignment detector 401, pilot block generator 411 and channel estimate acquisition section 421 carry out a channel estimation processing to obtain the channel
5 estimates of the data symbols. The channel estimation processing is the same as that of the channel estimation unit 100 (Fig. 2) of the first embodiment in accordance with the present invention.

At step S504, the pilot symbol eliminator 429
10 obtains a data symbol sequence by removing the pilot symbols from the combined symbol sequence on the basis of the detection result by the slot alignment detector 401.

At step S505, the data symbol sequence
15 compensator 430 compensates for the channel fluctuations in the data symbol sequence using the channel estimates $\tilde{\xi}$ obtained at step S503. More specifically, it compensates for the channel fluctuations in the data symbols by multiplying the
20 data symbol sequence by the complex conjugates of the channel estimates $\tilde{\xi}$.

At step S506, the RAKE combiner 432, deinterleaver 434 and Viterbi decoder 436 generate the data sequence by demodulating the compensated
25 data symbol sequence. The RAKE combiner 432 carries out the in-phase combining of the compensated data

symbol sequence fed from individual RAKE fingers.

Thus, the receiving processing can achieve highly accurate channel estimation, and the compensation for the channel fluctuations in the data symbol sequence.

[THIRD EMBODIMENT]

Fig. 6 is a block diagram showing a configuration of a CDMA transceiver as a third embodiment in accordance with the present invention. A CDMA transceiver 600 of the present embodiment comprises a transmitting processor 610 and a receiving processor 620. In the present embodiment, this station (the present CDMA transceiver) exchanges power control symbols with a party station. The power control symbols are symbols (a command) for controlling power of the data symbols and pilot symbols.

Fig. 7 shows a configuration of the transmitting processor 610, and Fig. 8 shows a configuration of the receiving processor.

As shown in Fig. 7, the transmitting processor 610 comprises a transmitting section 710, a channel encoder 722, an inserting section 724, a combiner 730 and a spreader 727. Although these components such as the channel encoder 722, inserting section

724 and so forth are implemented in the form of software using a DSP (and a memory that stores programs) 720 in the present embodiment, they can be implemented with hardware.

5 Fig. 9 is a flowchart illustrating a transmitting processing by the transmitting processor of the CDMA transceiver of the present embodiment. First, at step S901, the channel encoder 722 generates a data symbol sequence by
10 modulating (encoding) a data sequence.

At step S902, the inserting section 724 divides the data symbol sequence into a plurality of slots, and inserts into the slots the power control symbols the party station uses to determine the power of
15 data symbols and pilot symbols to be transmitted from the party station to the present station.

At step S903, the combiner 730 generates a combined symbol sequence by inserting the pilot symbols into the individual slots of the data symbol
20 sequence. The power control symbols can be inserted after the pilot symbols are inserted.

Fig. 10 is a diagram illustrating an example of the combined symbol sequence into which the power control symbols are inserted.

25 Although the combined symbol sequence is generated which includes the data symbols, pilot

symbols and power control symbol in the present embodiment, other types of combined symbol sequences can be generated.

Returning to Fig. 9, at step S904, the spreader
5 727 spreads the combined symbol sequence to generate a transmitted signal (spread combined symbol sequence).

At step S905, the transmitting section 710
transmits the transmitted signal with carrying out
10 the power control slot by slot in accordance with a power control symbol sequence which is sent from the party station to the present station. Incidentally, the division of the symbols into a plurality of slots can be performed immediately before the
15 transmission instead of carrying out at steps S902 and S903.

Next, as shown in Fig. 8, the receiving
processor 620 comprises a receiving section 810, a
matched filter 825, a slot alignment detector 801, a
20 pilot block generator 811, a channel estimate acquisition section 821, a pilot symbol eliminator 829, a data symbol sequence compensator 830, a RAKE combiner 832, a deinterleaver 834, a Viterbi decoder 836, a power control symbol generator 838 and a
25 power control symbol sequence extracting section 840. Although these components such as the matched

filter 825, slot alignment detector 801 and so forth
are implemented in the form of software using a DSP
(and a memory that stores programs) 820 in the
present embodiment, they can be implemented with
5 hardware. The structure and functions of the slot
alignment detector 801, pilot block generator 811
and channel estimate acquisition section 821 are the
same as those of their counterparts of the channel
estimation unit 100 of the first embodiment in
10 accordance with the present invention, and the
structure and functions of the receiving section
810, matched filter 825 and so forth are the same as
those of their counterparts of the CDMA receiver of
the second embodiment. Accordingly, the receiving
15 processor 620 carries out the same processings as
those of the CDMA receiver of the second embodiment
(Fig. 5) in accordance with the present invention.

The power control symbol generator 838 measures
the SNIR from the pilot symbols extracted or the
20 pilot blocks generated by the pilot block generator
811, and generates the power control symbols in
response to the measured values. As a measuring
method of the SNIR, there is a method of measuring
it by obtaining the average and variance of the
25 received signal. The SNIR measurement can also be
achieved using a data symbol sequence fed back after

decision. The power control symbols generated here are supplied to the inserting section 724 of the transmitting processor 610, which inserts them into the data symbol sequence to be transmitted when
5 transmitting the next signal to the party station. Receiving the symbols, the party station uses them when transmitting a signal to the present station.

The power control symbol sequence extracting section 840 extracts from the data symbol sequence
10 the power control symbol sequence, and supplies it to the transmitting section 710 of the transmitting processor 610 to be used when transmitting the next signal to the party station.

The transmission of the power control symbol
15 sequence can be unidirectional rather than bidirectional. For example, the power control symbol sequence can be transmitted only from a base station to a mobile station to control the (transmission) power of only a reverse channel (from
20 the mobile station to the base station) in communications between the two stations.

Thus, the transceiver can achieve in its processing highly accurate channel estimation and compensation for the channel fluctuations in the
25 data symbol sequence.

As described above, the present invention can

achieve, when performing the channel estimation of the data symbols, the highly accurate channel estimation by obtaining highly accurate channel estimates by calculating the sum of the pilot symbols which are appropriately weighted in the plurality of slots before and after the slot, to which the data symbol to be subjected to the channel estimation belongs, by using appropriate weighting factors for individual data symbols in each slot.

10 The highly accurate channel estimation together with the compensation for the channel fluctuations in the data symbols on the basis of the channel estimation makes it possible to decide the absolute phases of individual data symbols by using the
15 absolute coherent detection, and to reduce the SNIR needed for achieving the desired receiving quality (receiving error rate). As a result, the transmission power can be reduced, and the capacity of the system in terms of the number of subscribers
20 can be increased.

CLAIMS:

1. A channel estimation unit for obtaining channel estimates of data symbols from pilot symbols in a combined symbol sequence which has a plurality of slots and includes the data symbols and the pilot symbols, said channel estimation unit comprising:

means for locating the pilot symbols in the combined symbol sequence;

means for generating pilot blocks by extracting the pilot symbols from two or more slots in the combined symbol sequence in accordance with a located result; and

means for obtaining the channel estimates of the data symbols by calculating a weighted sum of averages of the pilot symbols in the individual pilot blocks,

wherein a magnitude of weighting differs between at least two data symbols in each slot.

20

2. A CDMA receiver which receives a combined symbol sequence that is spread, has a plurality of slots, and includes data symbols and pilot symbols, and which generates a data sequence, said CDMA receiver comprising:

means for receiving the spread combined symbol

sequence;

means for generating a combined symbol sequence
by despread the spread combined symbol sequence;

means for locating the pilot symbols in the
5 combined symbol sequence;

means for generating pilot blocks by extracting
the pilot symbols from two or more slots in the
combined symbol sequence in accordance with a
located result;

10 means for obtaining channel estimates of the
data symbols by calculating a weighted sum of
averages of the pilot symbols in the individual
pilot blocks;

means for obtaining a data symbol sequence by
15 eliminating the pilot symbols from the combined
symbol sequence in accordance with the located
result;

means for compensating for channel fluctuations
in the data symbol sequence by using the channel
20 estimates of the data symbols; and

means for generating the data sequence by
demodulating the data symbol sequence compensated
for,

wherein a magnitude of weighting differs between
25 at least two data symbols in each slot.

3. A CDMA transceiver including a transmitting processor and a receiving processor, said transmitting processor comprising:

means for generating a data symbol sequence by
5 modulating a data sequence;

means for generating a combined symbol sequence by inserting pilot symbols into the data symbol sequence;

means for generating a spread combined symbol
10 sequence by spreading the combined symbol sequence;
and

means for transmitting the spread combined symbol sequence,

wherein the spread combined symbol sequence to
15 be transmitted has a plurality of slots, and
said receiving processor comprising:

means for receiving the spread combined symbol sequence;

means for generating the combined symbol
20 sequence by despread the spread combined symbol sequence;

means for locating the pilot symbols in the combined symbol sequence;

means for generating pilot blocks by extracting
25 the pilot symbols from two or more slots in the combined symbol sequence in accordance with a

located result;

means for obtaining channel estimates of the data symbols by calculating a weighted sum of averages of the pilot symbols in the individual
5 pilot blocks;

means for obtaining a data symbol sequence by eliminating the pilot symbols from the combined symbol sequence in accordance with the located result;

10 means for compensating for channel fluctuations in the data symbol sequence by using the channel estimates of the data symbols; and

means for generating the data sequence by demodulating the data symbol sequence compensated
15 for,

wherein a magnitude of weighting differs between at least two data symbols in each slot.

4. The CDMA transceiver as claimed in claim 3,
20 wherein said transmitting processor further comprises means for inserting into the data symbol sequence a power control symbol sequence for controlling power of the data symbols and pilot symbols.

25

5. The CDMA transceiver as claimed in claim 4,

wherein said receiving processor further comprises means for measuring from the pilot symbols a signal-to-noise and interference power ratio, and for generating the power control symbol sequence from
5 the signal-to-noise and interference power ratio.

6. The CDMA transceiver as claimed in any one of claims 3-5, wherein said receiving processor further comprises means for extracting, from the data symbol
10 sequence compensated for, the power control symbol sequence for controlling power of the data symbols and pilot symbols, and said means for transmitting the spread combined symbol sequence transmits the spread combined symbol sequence in accordance with
15 the power control symbol sequence.

7. The equipment as claimed in any one of claims 1-6, wherein the power of the data symbols and pilot symbols is controlled on a slot by slot basis.

20 8. The equipment as claimed in any one of claims 1-7, wherein the number of data symbols included in each slot of the combined symbol sequence is the same, and the number of pilot symbols included in
25 each slot of the combined symbol sequence is the same.

9. The equipment as claimed in any one of claims 1-8, wherein the pilot blocks each consist of all the pilot symbols in each slot.

5

10. The equipment as claimed in any one of claims 1-9, wherein when obtaining the channel estimates of the data symbols in an n th slot in the combined symbol sequence, where n is an integer, the pilot blocks are generated from $(n-K+1)$ th slot to $(n+K)$ th slot in the combined symbol sequence, where K is a natural number.

11. The equipment as claimed in any one of claims 1-10, wherein the pilot blocks closer to the data symbol with which the channel estimate is to be obtained have a greater weight.

12. A channel estimation method of obtaining channel estimates of data symbols from pilot symbols in a combined symbol sequence which has a plurality of slots and includes the data symbols and the pilot symbols, said channel estimation method comprising the steps of:

25 locating the pilot symbols in the combined symbol sequence;

generating pilot blocks by extracting the pilot symbols from two or more slots in the combined symbol sequence in accordance with a located result; and

- 5 obtaining the channel estimates of the data symbols by calculating a weighted sum of averages of the pilot symbols in the individual pilot blocks, wherein a magnitude of weighting differs between at least two data symbols in each slot.

10

13. A CDMA receiving method of generating a data sequence by receiving a combined symbol sequence that has a plurality of slots, includes data symbols and pilot symbols, and is spread, said CDMA

- 15 receiving method comprising the steps of:

receiving the spread combined symbol sequence;
generating the combined symbol sequence by
despreading the spread combined symbol sequence;
locating the pilot symbols in the combined
20 symbol sequence;

generating pilot blocks by extracting the pilot symbols from two or more slots in the combined symbol sequence in accordance with a located result;

- obtaining channel estimates of the data symbols
25 by calculating a weighted sum of averages of the pilot symbols in the individual pilot blocks;

obtaining a data symbol sequence by eliminating the pilot symbols from the combined symbol sequence in accordance with the located result;

compensating for channel fluctuations in the
5 data symbol sequence by using the channel estimates of the data symbols; and

generating the data sequence by demodulating the data symbol sequence compensated for,

wherein a magnitude of weighting differs between
10 at least two data symbols in each slot.

14. A CDMA transmitting and receiving method comprising the steps of:

on a transmitting side,

15 generating a data symbol sequence by modulating a data sequence;

generating a combined symbol sequence by inserting pilot symbols into the data symbol sequence;

20 generating a spread combined symbol sequence by spreading the combined symbol sequence; and

transmitting the spread combined symbol sequence,

wherein the spread combined symbol sequence to
25 be transmitted has a plurality of slots, and
on a receiving side,

receiving the spread combined symbol sequence;
generating the combined symbol sequence by
despreading the spread combined symbol sequence;
locating the pilot symbols in the combined
5 symbol sequence;

generating pilot blocks by extracting the pilot
symbols from two or more slots in the combined
symbol sequence in accordance with a located result;

obtaining channel estimates of the data symbols
10 by calculating a weighted sum of averages of the
pilot symbols in the individual pilot blocks;

obtaining a data symbol sequence by eliminating
the pilot symbols from the combined symbol sequence
in accordance with the located result;

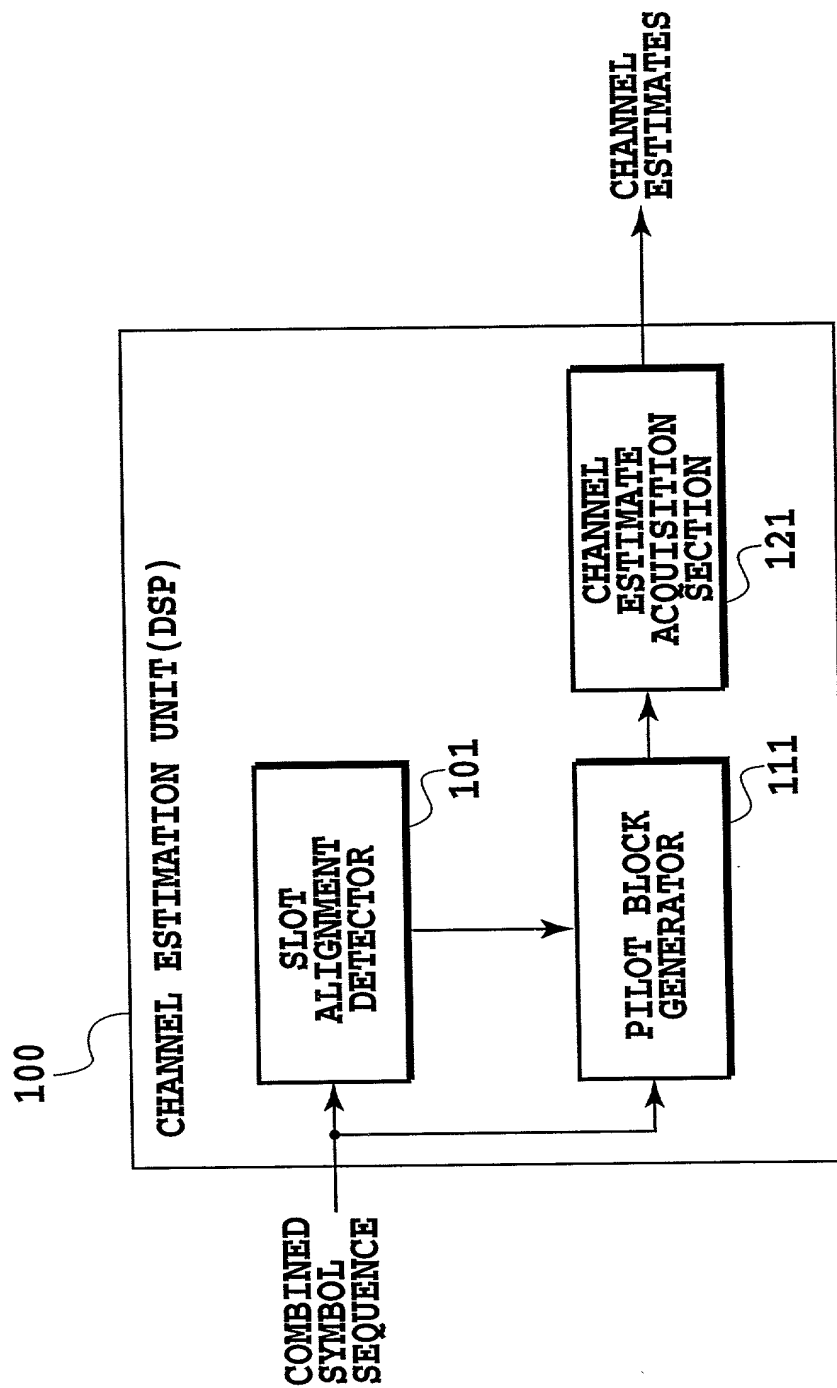
15 compensating for channel fluctuations in the
data symbol sequence by using the channel estimates
of the data symbols; and

generating the data sequence by demodulating the
data symbol sequence compensated for,

20 wherein a magnitude of weighting differs between
at least two data symbols in each slot.

ABSTRACT

There are provided a channel estimation unit for achieving highly accurate channel estimation, a CDMA receiver and a CDMA transceiver with the channel estimation unit. Channel estimates of data symbols are obtained from pilot symbols in a combined symbol sequence which has a plurality of slots and includes the data symbols and the pilot symbols. First, the pilot symbols in the combined symbol sequence are located. Second, pilot blocks are generated by extracting the pilot symbols from two or more slots in the combined symbol sequence. Third, channel estimates of the data symbols are obtained by calculating a weighted sum of averages of the pilot symbols in the individual pilot blocks. The weighted sum is carried out using appropriate weighting factors for individual data symbols in each slot. This enables highly accurate channel estimation.

**FIG.1**

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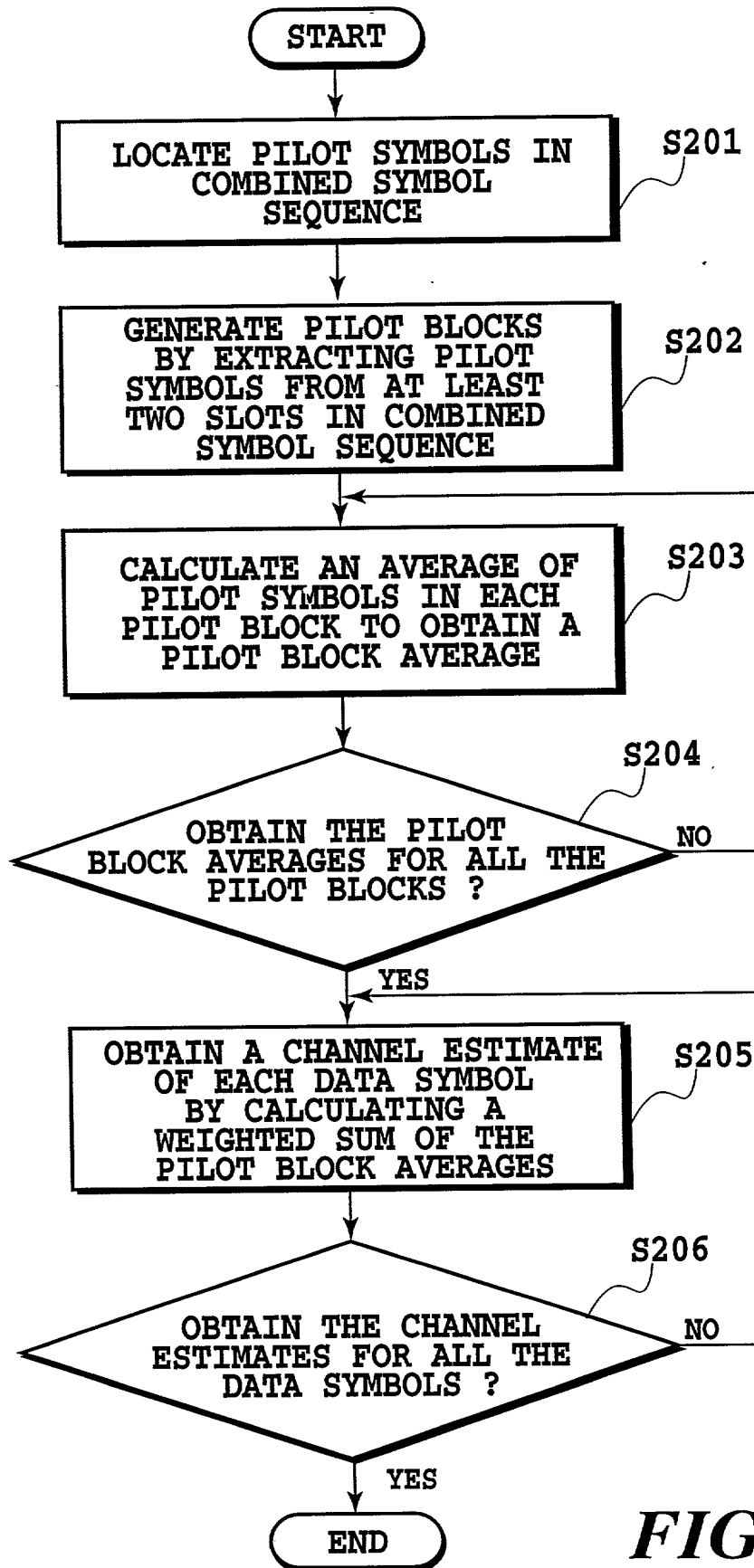
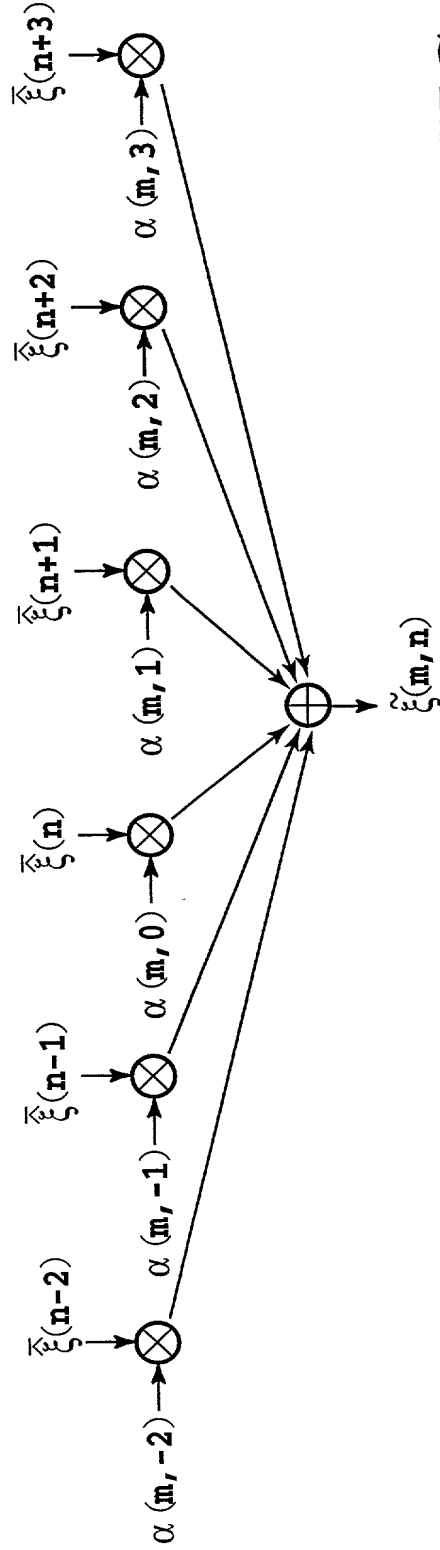
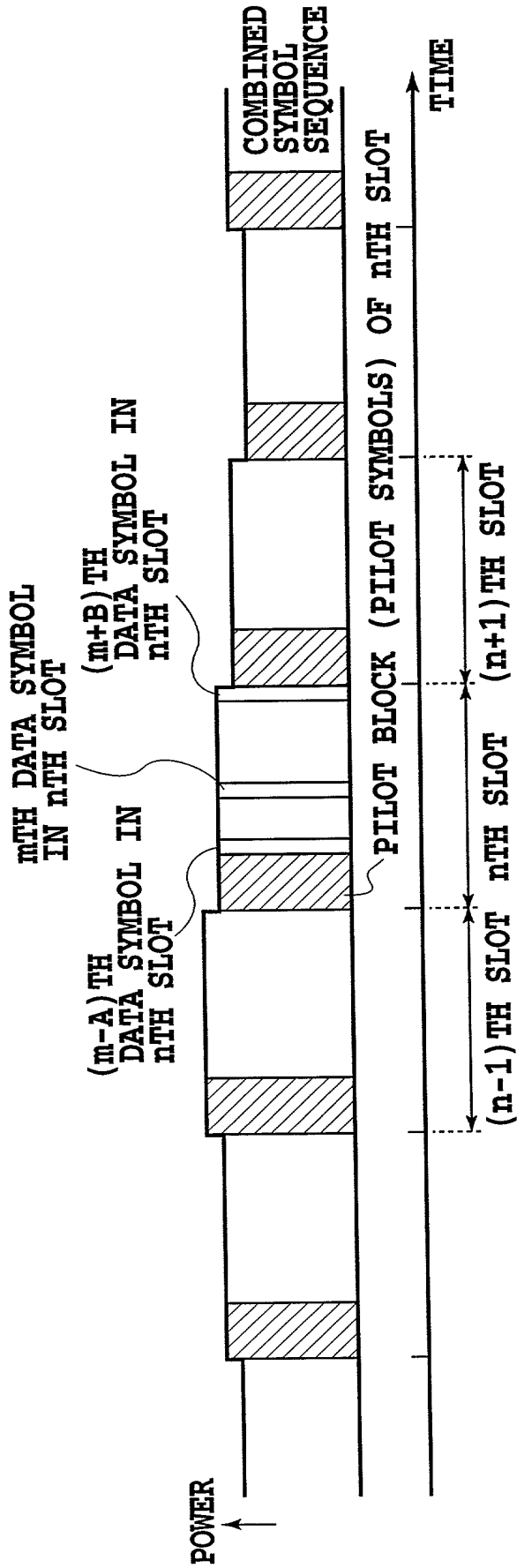


FIG.2



CHANNEL ESTIMATE OF mTH DATA SYMBOL IN nTH SLOT **FIG.3**

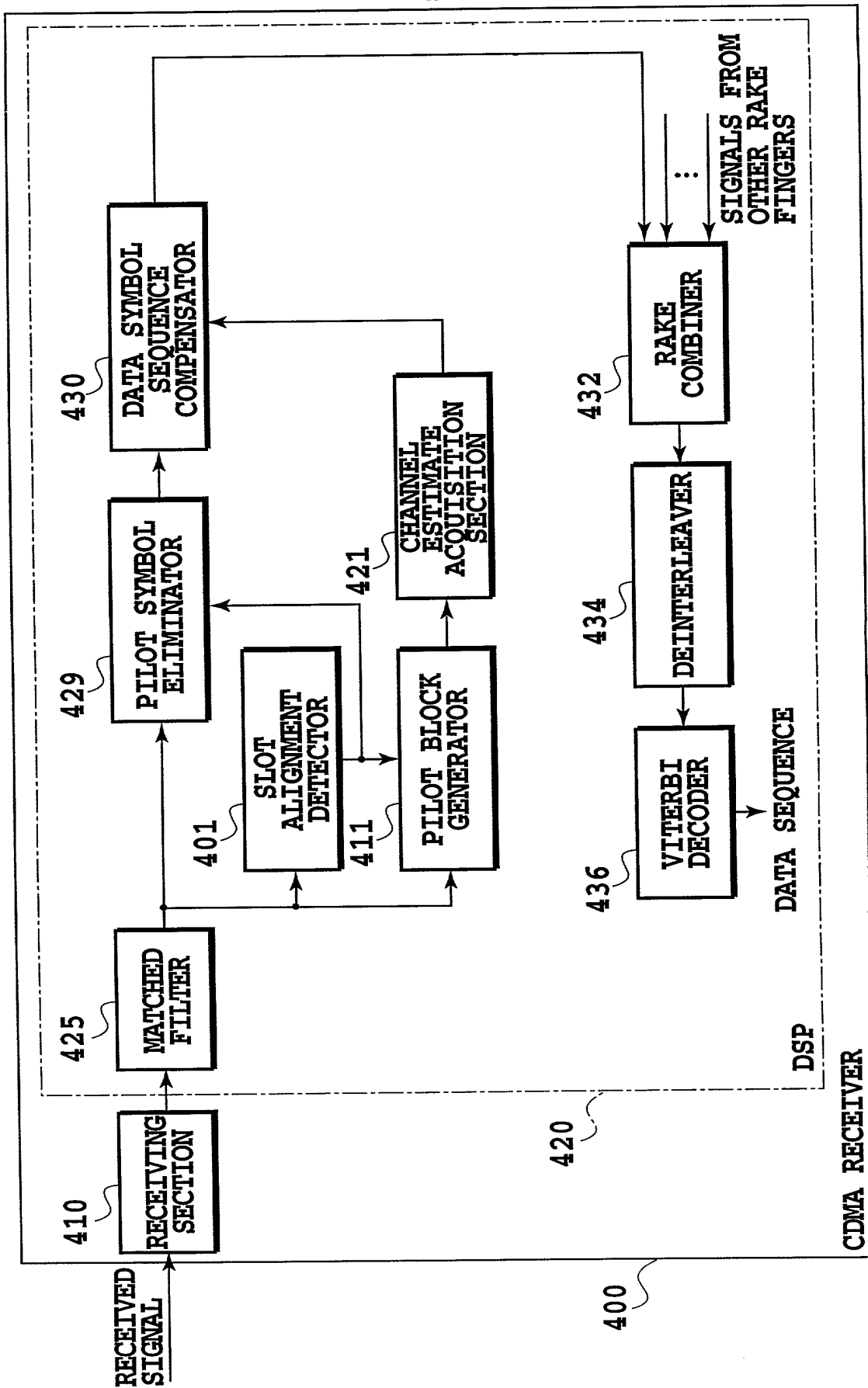


FIG. 4

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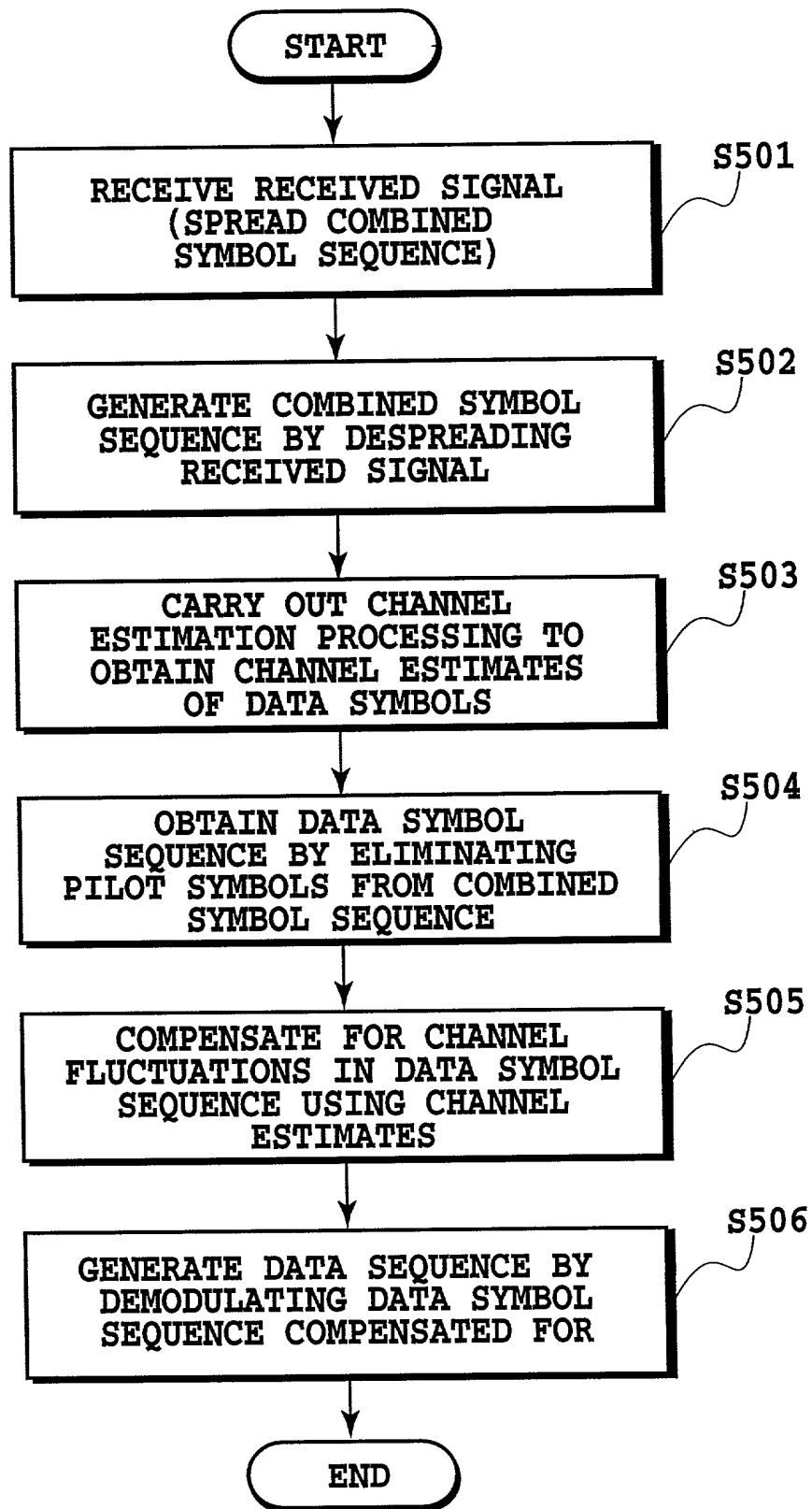


FIG.5

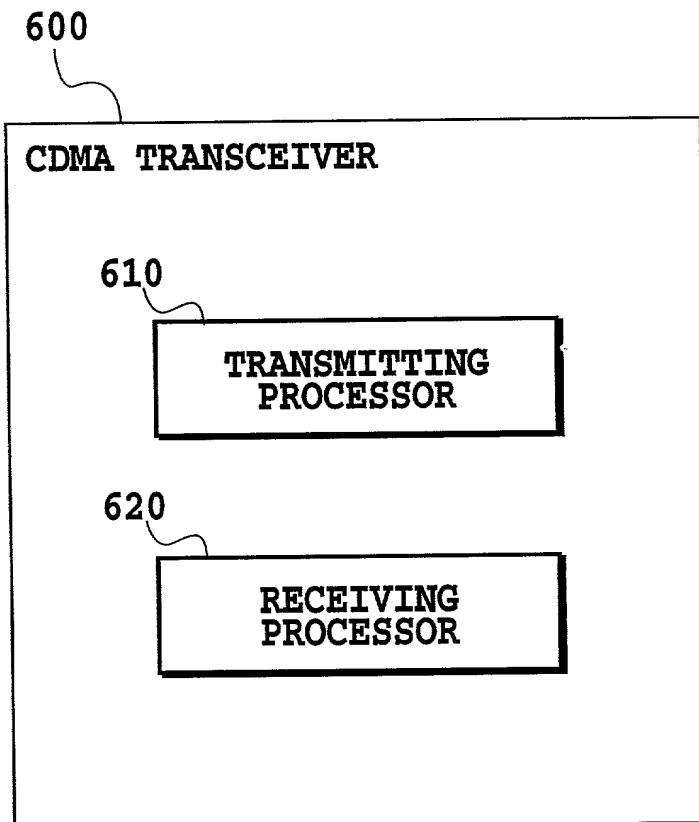


FIG.6

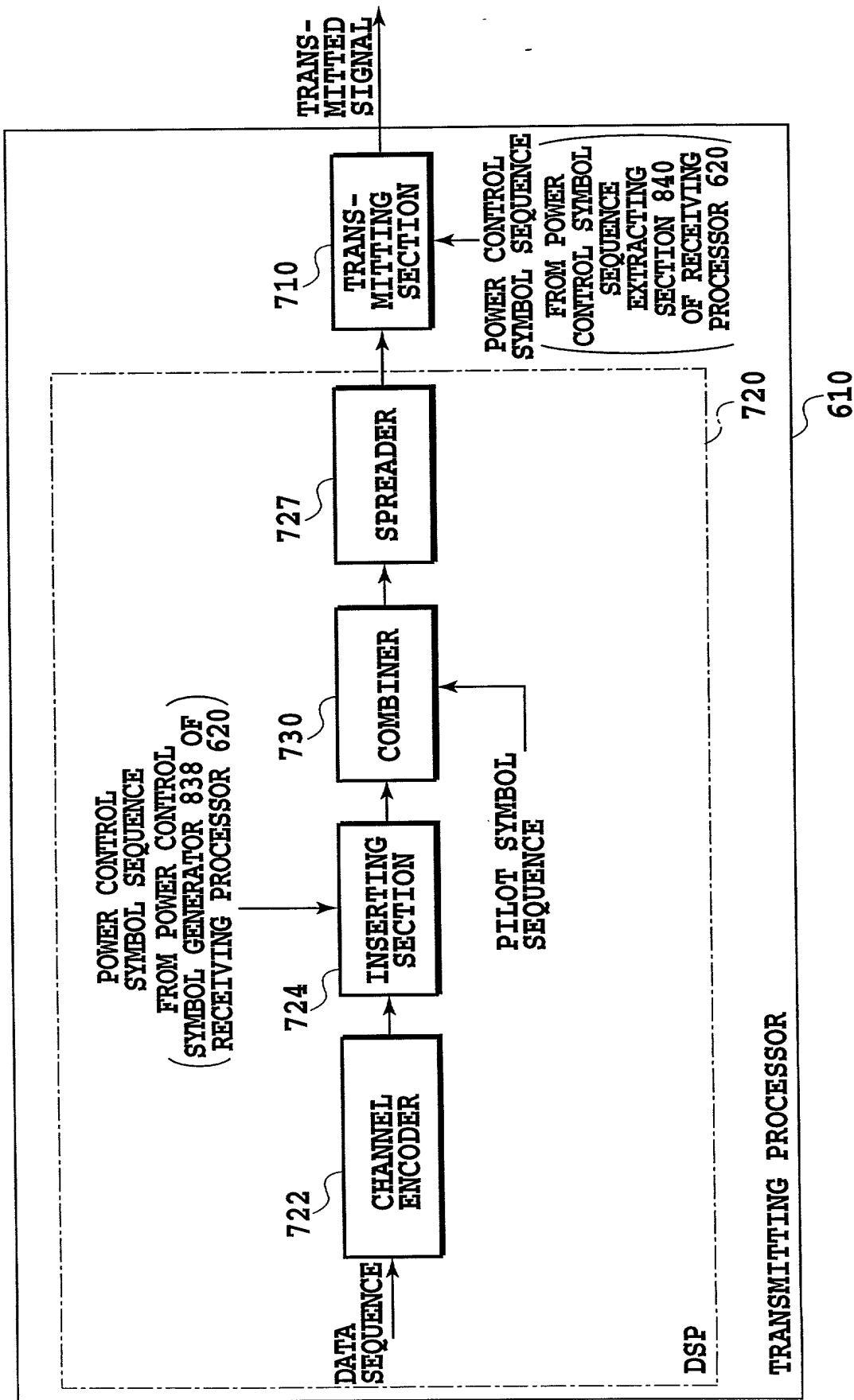


FIG.7

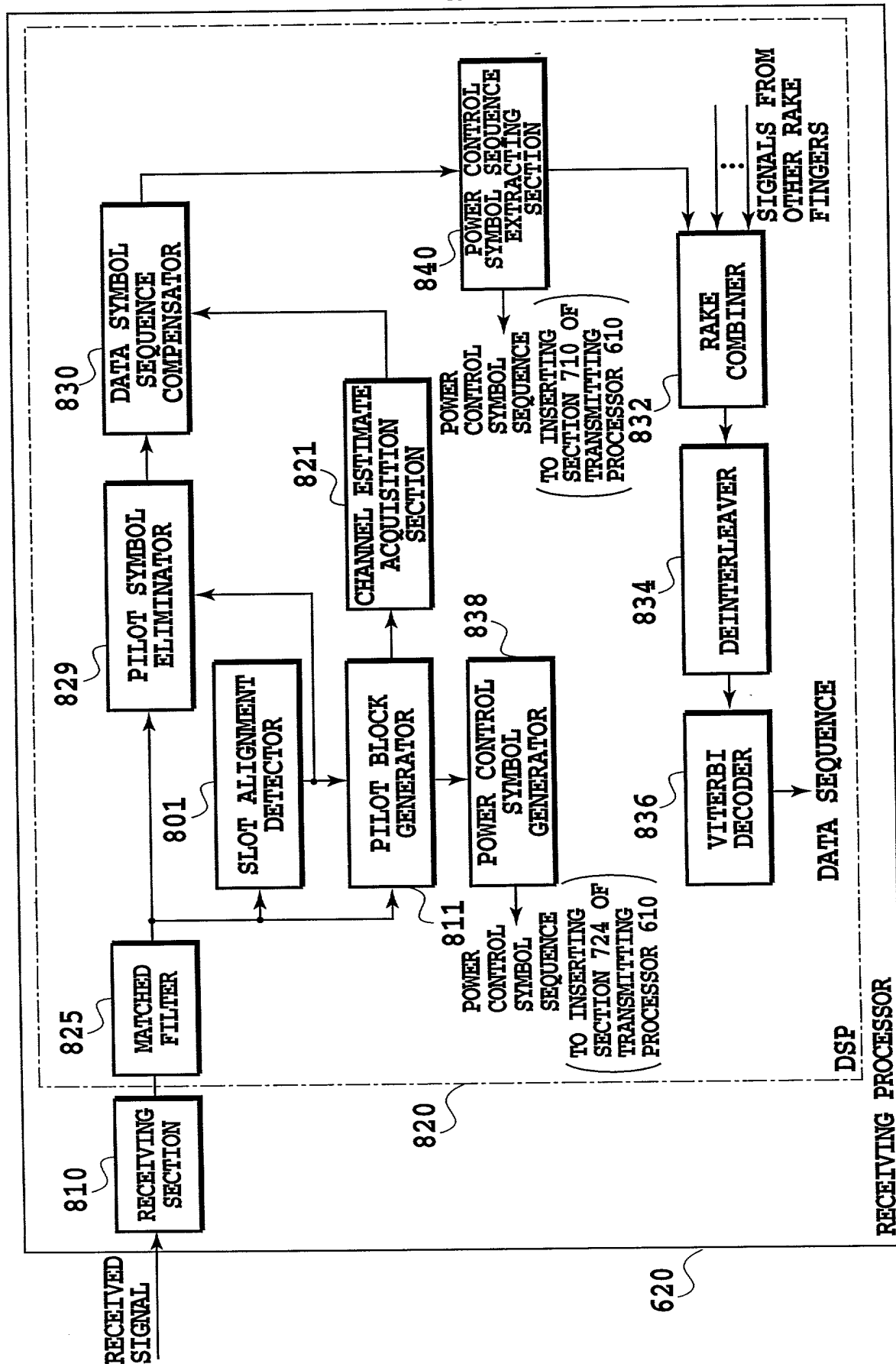


FIG.8

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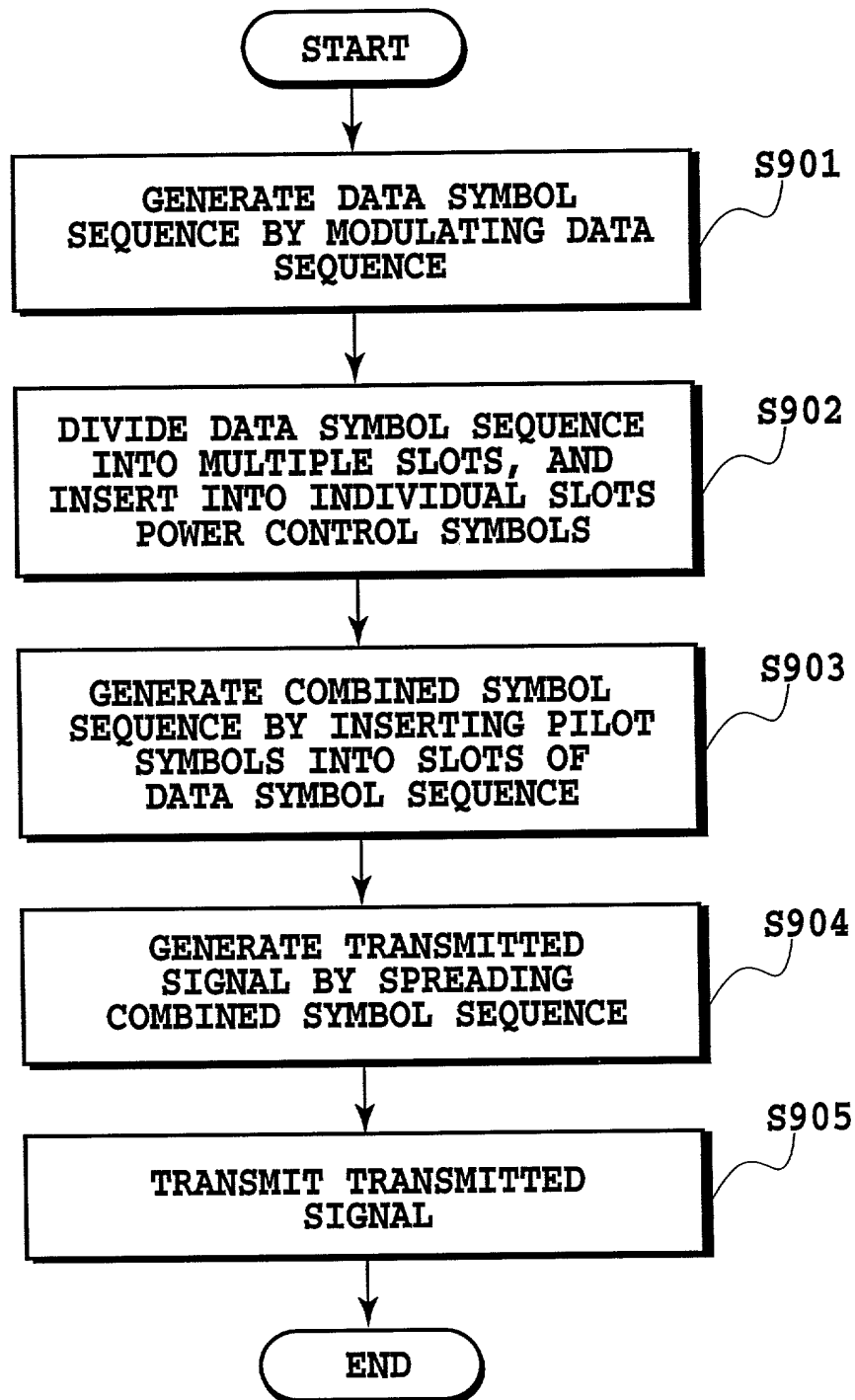


FIG.9

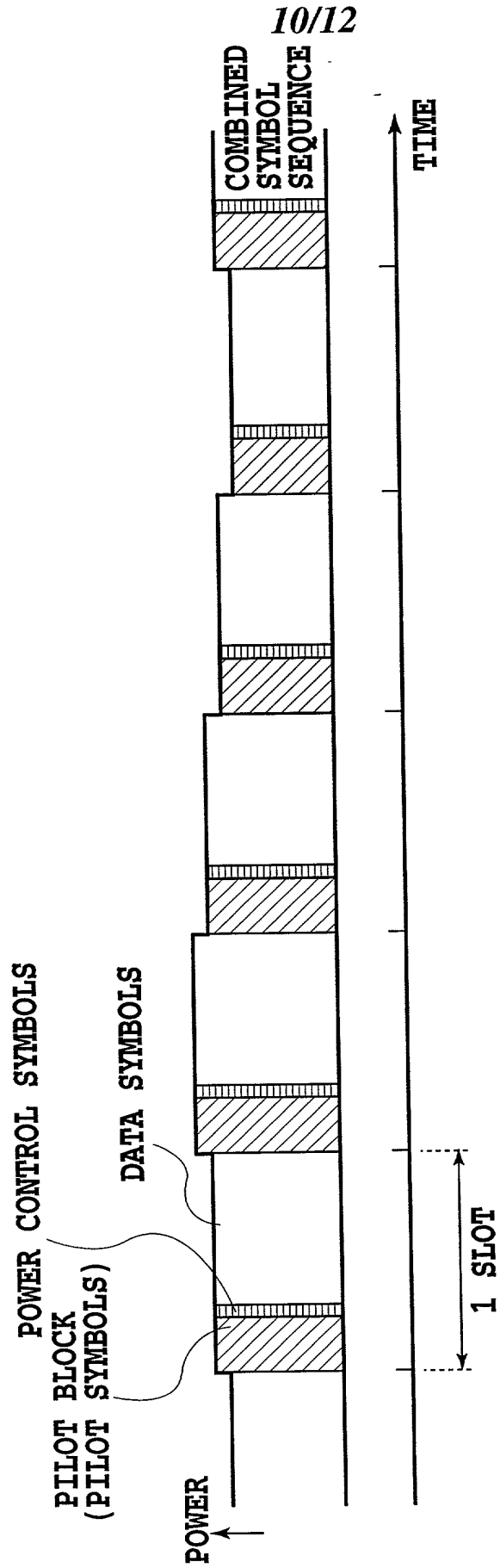
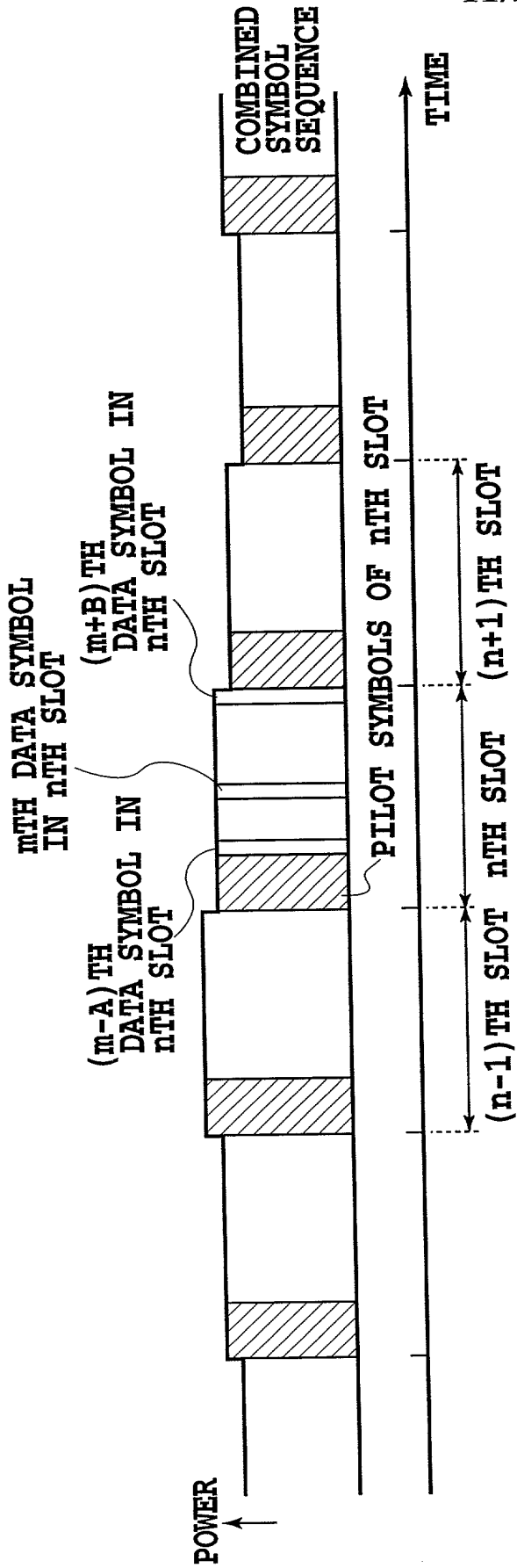
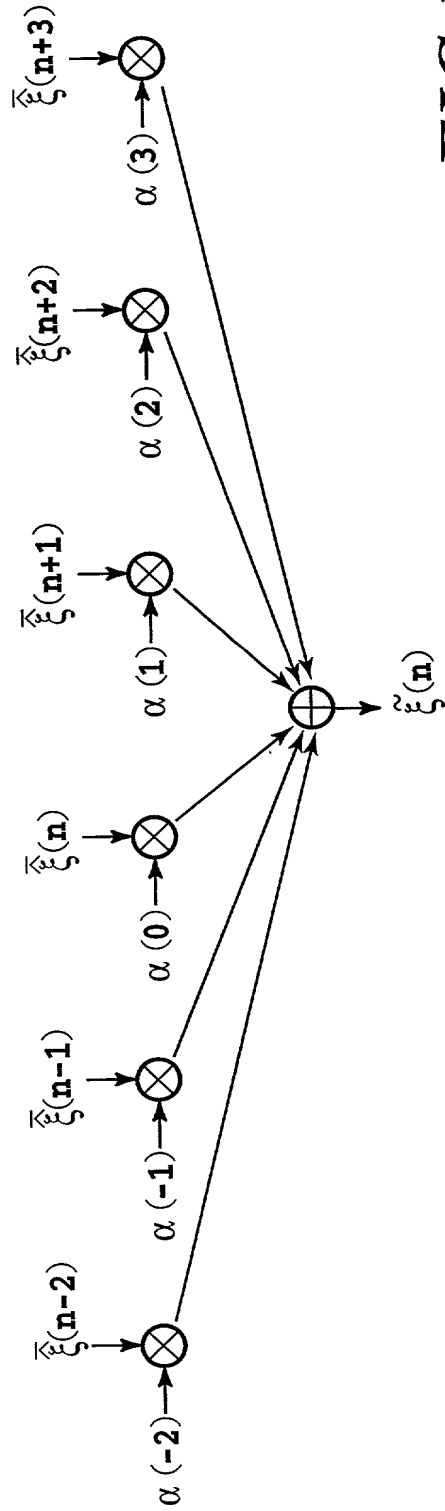


FIG.10



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CHANNEL ESTIMATE COMMON TO DATA SYMBOLS IN n TH SLOT **FIG. 11**

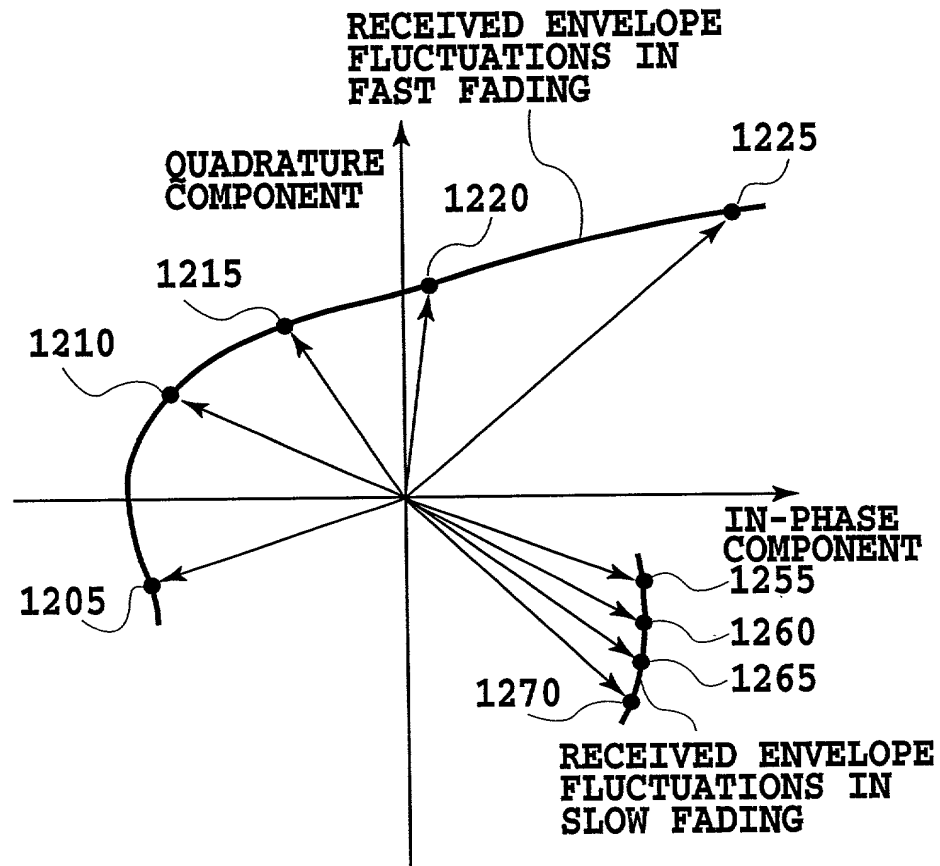


FIG.12

DECLARATION AND POWER OF ATTORNEY FOR PATENT APPLICATION

(COMPLETE IF KNOWN)

Application Number	
Filing Date	
Group Art Unit	
Examiner	

Attorney Docket Number	
First Named Inventor	ABETA

This declaration is (check one):

- ☐ submitted with initial filing;
- ☐ submitted after initial filing;
- ☐ a supplemental declaration.

This application is of the following type:

- ☐ utility;
- ☐ design;
- ☒ national stage of PCT;
- ☐ divisional, continuation or continuation-in-part.

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

CHANNEL ESTIMATION UNIT, AND CDMA RECEIVER AND CDMA TRANSCEIVER WITH
CHANNEL ESTIMATION UNIT

the specification of which: (check one)

- ☐ is attached hereto; or
- ☐ was filed on _____ as U.S. Application No. _____ and is/was amended on _____ (if applicable);
- ☒ was described and claimed in PCT International Application No. PCT/JP98/05727, filed on December 17, 1998 and was amended under PCT Article 19 on _____ (if applicable).

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, §1.56.

I hereby identify below, and where indicated claim foreign priority benefits under Title 35, United States Code §§ 119(a)-(d) or §§ 365(a)-(b) of any foreign application(s) for patent or inventor's certificate or of any PCT international application(s) designating at least one country other than the United States of America, filed within 12 months (6 months for design) prior to

this application, and have also identified below any foreign application(s) for patent or inventor's certificate or any PCT international application(s) designating at least one country other than the United States of America filed by me on the same subject matter having a filing date before that of the application(s) on which priority is claimed (if any):

Foreign/PCT Application Number	Country	Filing Date (MM/DD/YYYY)	Priority Claimed	
349,609/1997	Japan	12/18/1997	<input checked="" type="checkbox"/> Yes	<input type="checkbox"/> No
			<input type="checkbox"/> Yes	<input type="checkbox"/> No
			<input type="checkbox"/> Yes	<input type="checkbox"/> No

I hereby claim the benefit under Title 35, United States Code, §119(e) of any United States provisional application(s) listed below (if any):

Provisional Application No.	Filing Date

I hereby claim the benefit under Title 35, United States Code, § 120 of any United States application(s), or § 365(c) of any PCT International Application designating the United States of America listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT international application in the manner provided by the first paragraph of Title 35, United States Code, § 112, I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, § 1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application:

U.S./PCT Parent Application No.	Filing Date	Status (Patented, Pending, or Abandoned)
PCT/JP98/05727	December 17, 1998	Pending

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

As a named inventor, I hereby appoint the following attorney(s) or agent(s) with full power of substitution and revocation to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith:

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(check one) Sheets containing additional joint inventors () are, (X) are not attached hereto.